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SEDIMENT IN STREAMS

Sources, Biological Effects, and Control

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that sediment in logged streams on the Queen Charlotte Islands, British Columbia, was mainly due to streambank erosion and landslides related to the logging. Where some British Columbia watersheds were logged to stream edges, Hogan (1986) recorded more debris torrents and thus increased sediment storage in the streambed, thereby reducing fish rearing habitat.

Sediment deposits in private forested watersheds in New Brunswick were compared between clear-cuts and controls (Welch et al. 1977). Sediment was 36% greater from clear-cut watersheds than from undisturbed watersheds; stream gravel and rock substrate were reduced and pool depths decreased in streams in the clear-cut watersheds. Logging in the clear-cut watersheds resulted in higher sediment production, the apparent result of lack of buffer strips, use of bulldozers in streambeds, and poor road design and maintenance.

In Nova Scotia, Rutherford (1986) observed the effects of 53 timber-harvest sites on Atlantic salmon streams (and revisited 47). He found siltation from initial construction at nearly 100% of the sites and concluded that logging road crossings (construction of culverts and bridges) caused most of the siltation.

The Logging Road

By far, the logging road produces the most sediment generated among forest management practices (Anderson 1971; Anderson et al. 1976; Cederholm et al. 1981; Furniss et al. 1991). Road construction also causes soil movements or landslides associated with road construction (Beschta 1978; Swanston 1991).

The density and length of logging road distribution can be major factors in determining the level of sediment production. For example, the greatest accumulation of fine sediments in streambeds occurred when the road area exceeded 2.5% of the total basin area (Cederholm et al. 1981). The authors also calculated that total road lengths of 2.5 km of road per square kilometer of the basin produced sediment more than four times natural rates. Consequently, the greatest attention to techniques to prevent sedimentation and restore damaged streams (in later sections of this volume) has been directed to the logging road.

Although the logging road has been identified as a singular sediment source, other miscellaneous sources appear in all other forestry operations that disturb the soil surface—such as log skidding, yarding (especially with tractors), site preparation, "hot burns" to remove slash (thus baring soil), heavy equipment operation, and bridging. Clear-cutting as a harvest technique has been broadly indicted many times as a major cause of eroded sediment in comparison with patch-cutting, selective cutting, and leaving buffer strips. However, all operations, it seems, must be serviced by roads. The latest summary on effects of road erosion and minimizing sediment from roads is by Furniss et al. (1991).

Finally, although the logging road has been identified as the primary sediment source—along with other sediment sources that are important in certain conditions—it should be emphasized that logging operations have many environmental effects, of which sediment production is only one. Other effects include increased amounts of woody debris that may clog stream channels and prevent fish movement; altered fish habitat in the channel; loss of riparian vegetation and resulting decreases in allochthonous inputs; elimination of streamside shade with consequent elevated water temperature; and, contrarily, an open canopy which allows more sunlight and potentially increased production by plants and invertebrates.

Whereas this volume is concerned with excess sediment as a major pollutant, several other reviews have stressed the need for more comprehensive assessment of forest management practices. Several authors (e.g., Everest et al. 1987) have pointed out that current practices in forest management have improved over the last two decades. Major changes have taken place in the Pacific Northwest, such as improved road engineering and treatment of slash. However, these authors also emphasized that sediment, although extremely important, should be integrated with total plans for forest management.

MINING

Mining operations produce immense quantities of sediments that can enter streams, elevating levels of suspended solids and turbidity, and creating deposits on streambeds. Fewer reports on sediment sources from mining appear in the biological literature than for agriculture and forestry, but local conditions have been cited as severe.

Four major forms of mining are identified: placer, surface, underground (Paone et al. 1978; Nelson et al. 1991), and sand and gravel extraction (Kanehl and Lyons 1992).

Placer mining consists of the removal of stream-transported and sorted mineral grains, often gold, from streambeds or other alluvial deposits. Surface mining includes strip mining and open-pit mining, often for coal, gold, copper, and iron ore. Underground mining uses drilled or dug shafts of various forms to extract metals and other minerals. Sand and gravel extractions are often done by dredging directly in streambeds, by excavating in stream-deposited floodplains (Kanehl and Lyons 1992), or in open-pit development in eskers and other glacial deposits removed from streams. Washing and grading operations for sand–gravel material, however, are often done using stream water, which might be returned with high sediment loads to channels.

All forms of mining can be important in the production of sediment. Two of these involve direct intrusion into streambeds or alluvial deposits: placer mining and sand–gravel extractions. However, both surface and underground mining have the potential to produce large quantities of waste materials such as spoils and tailings on the surface, which then may be subject to erosion (Hill 1975).

This volume is concerned mostly with four mining sources of sediment: placer, surface, and underground mining, and sand–gravel extractions. Stream pollution by toxic materials—sulphuric acid, metal ores, and ore-processing chemicals—can be extremely toxic to stream biota, but will not be addressed in this review. Nelson et al. (1991) provide good leads into the literature.

Placer Mining

It may be difficult to imagine the historic sourdough prospector—with his grubstake of food, gold pans, and pick-and-shovel loaded on a solitary burro, panning for tiny flakes and nuggets from a western mountain creek—having